BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Proposed Simplification of the CSM-Digital Autopilots - Case 310

DATE: March 27, 1968

FROM: A. Heiber
F. La Piana

ABSTRACT

This memorandum describes proposed simplifications of the CSM digital autopilots (DAP). The objective is to determine the feasibility of using half the fixed and erasable memory of the AGC.

It appears possible that the memory requirement for the CSM-TVC DAP maybe reduced by 50%; the CSM-RCS by 40%; and the CM Entry DAP by 80%.

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MEMORANDUM FOR FILE

This memorandum describes proposed simplifications of the CSM DAP. The objective is to determine the feasibility of using half the fixed and erasable memory of the AGC.

The following recommendations were made for the CSM-TVC DAP:

1. Eliminate the thrust misalignment corrector (TMC) loop.

2. Implement a sixth order filter for both the CSM and CSM/LM.

3. Implement the filter in cascaded nodal form, single precision.

4. Use constant gain for CSM; gain change for CSM/LM.

The higher gain sixth order filter has recently been proposed by MIT/IL. We would take advantage of the higher gain to eliminate the TMC loop.

The autopilots in the Sundisk program have been compared to the proposed designs in a simulation that was built for the Bellcomm Powered Flight Simulator.

The CSM and CSM/LM vehicle configurations were simulated for each autopilot with a 1/2 degree step input and a transient due to a 1/2 degree mistrim between the thrust vector and the c.g.

In the case of the CSM, the response to the step input is shown in figures 1 and 2. The rise time, overshoot and convergence to final value are superior for the proposed design. There was no c.g. offset for these runs. The step input occurs at 3.83 seconds.

For the CSM, the response to an initial 1/2 degree offset of the c.g. is shown in figures 3 and 4. In order to understand the comparison it is necessary to understand the effect of the TMC loop. The TMC loop acts as a low frequency integrator on the output of the digital filter. It picks up the D.C. component of the digital filter output and feeds it back to the filter output. The D.C. component is equal to the c.g. offset. As a result the TMC loop picks up the value of the c.g. offset and the output of the digital filter can go to zero in the steady state. This implies a zero input error signal to the digital filter. Therefore when the TMC loop is present the vehicle terminal attitude should be the commanded value, zero in the present case.

When the TMC loop is not present, as in the proposed design, the vehicle must hold an attitude offset to compensate for the c.g. displacement. The attitude offset will be equal to the c.g. angular displacement divided by the steady state gain of the filter. The effect of the offset will be taken out by the guidance commands when the guidance loop is closed.

Therefore the significant information in figures 3 and 4 are the rise time and overshoot and not the terminal value.

Figures 5 and 6, and 7 and 8 are a repeat of the above for the CSM/LM vehicle configuration.

These runs demonstrate the feasibility and, in fact, the superiority of the simplified TVC DAP's.

For the CSM-RCS DAP we recommend a simple, digital version of the pulse ratio modulator (PRM). This type of autopilot has been designed and tested at Bellcomm by E. A. Nussbaumer. The PRM is relatively insensitive to off-nominal vehicle parameters.

For the CM Entry DAP we recommend that the external atmospheric DAP use the same autopilot provided for the CSM-RCS. For the intra-atmospheric DAP we would use the roll portion of the CSM-RCS DAP and the same pitch and yaw rate dampers as MIT/IL.

Conclusion

The feasibility of the simplified CSM-TVC DAP has been demonstrated. It is estimated that the simplified DAP would use 50% of the memory required for the present design.

The proposed CSM-RCS DAP is a proven approach and would use approximately 60% of the present memory requirement.

The greatest percentage savings are possible with the entry DAP. Only the pitch and yaw rate dampers must be provided and these are trivial. Therefore it is estimated that 80% of the memory requirement for entry DAP can be saved.

A. Heiber

F. La Piana

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Attachments
Figures 1 thru 8

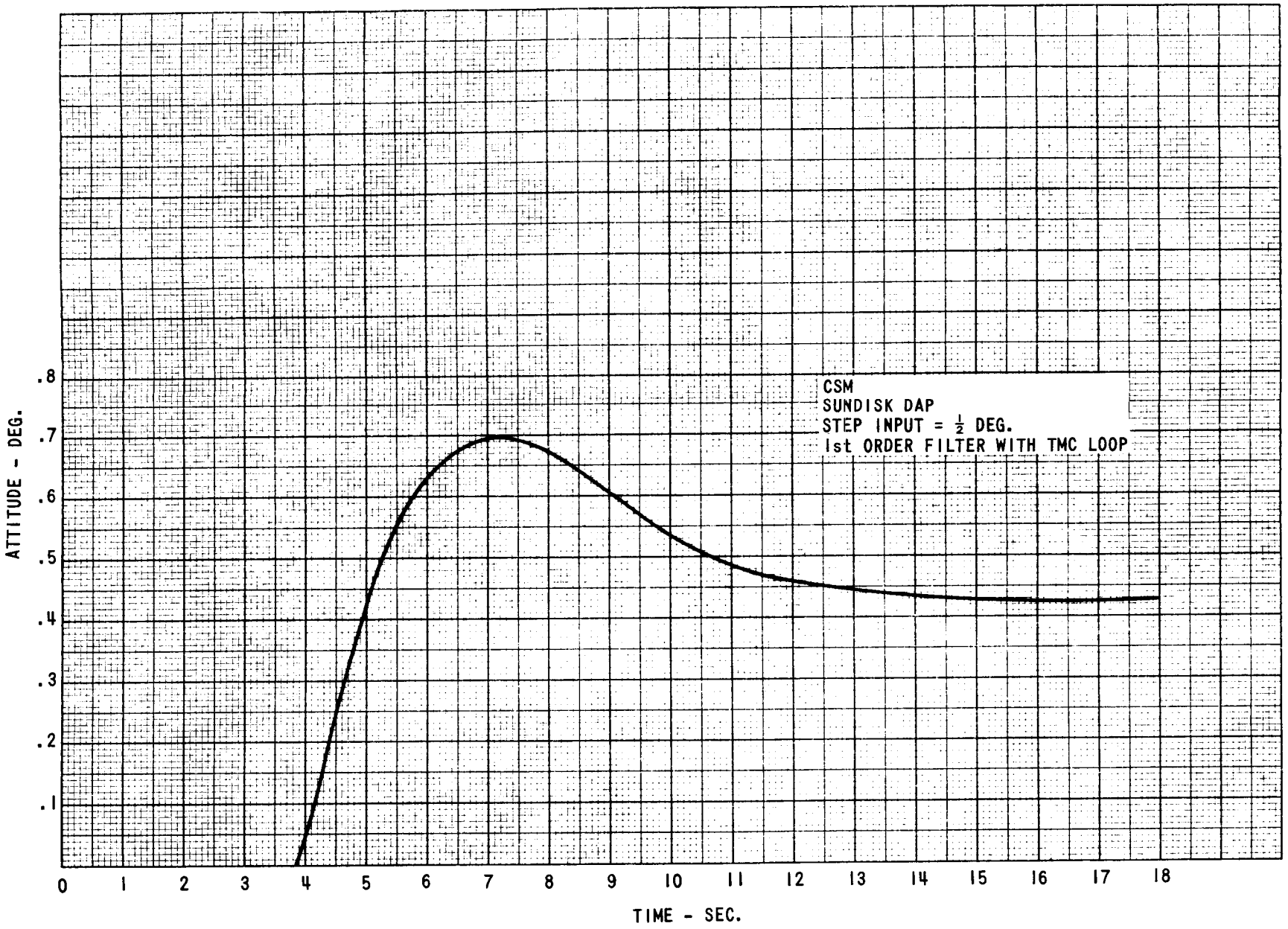
CSM
SUNDISK DAP
STEP INPUT = ½ DEG.
1st ORDER FILTER WITH TMC LOOP
ATTITUDE - DEG.
.8
.7
.6
.5
.4
.3
.2
.1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
TIME - SEC.

FIGURE 1

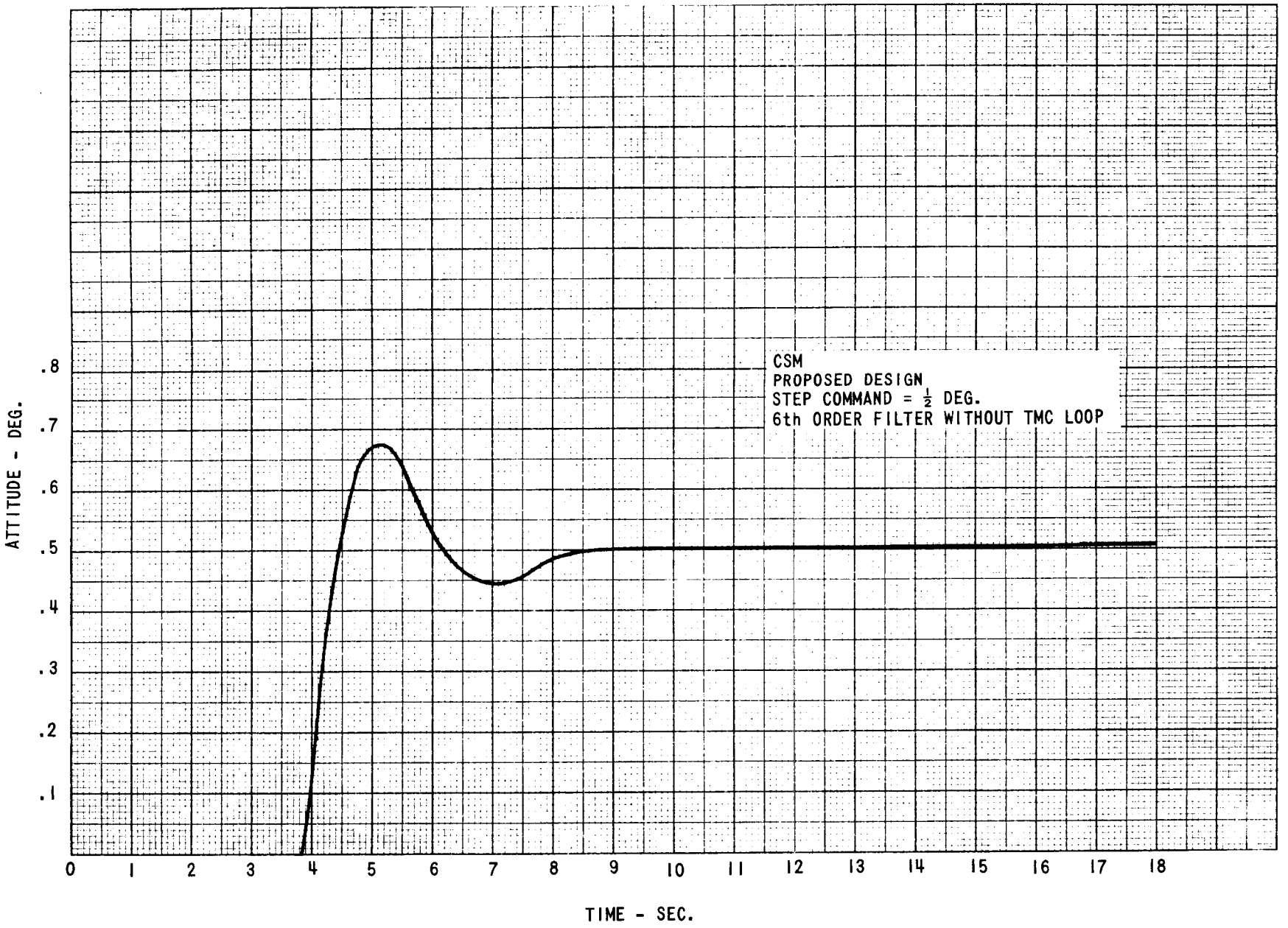
CSM
PROPOSED DESIGN
STEP COMMAND = ½ DEG.
6th ORDER FILTER WITHOUT TMC LOOP
ATTITUDE - DEG.
.8
.7
.6
.5
.4
.3
.2
.1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
TIME - SEC.

FIGURE 2

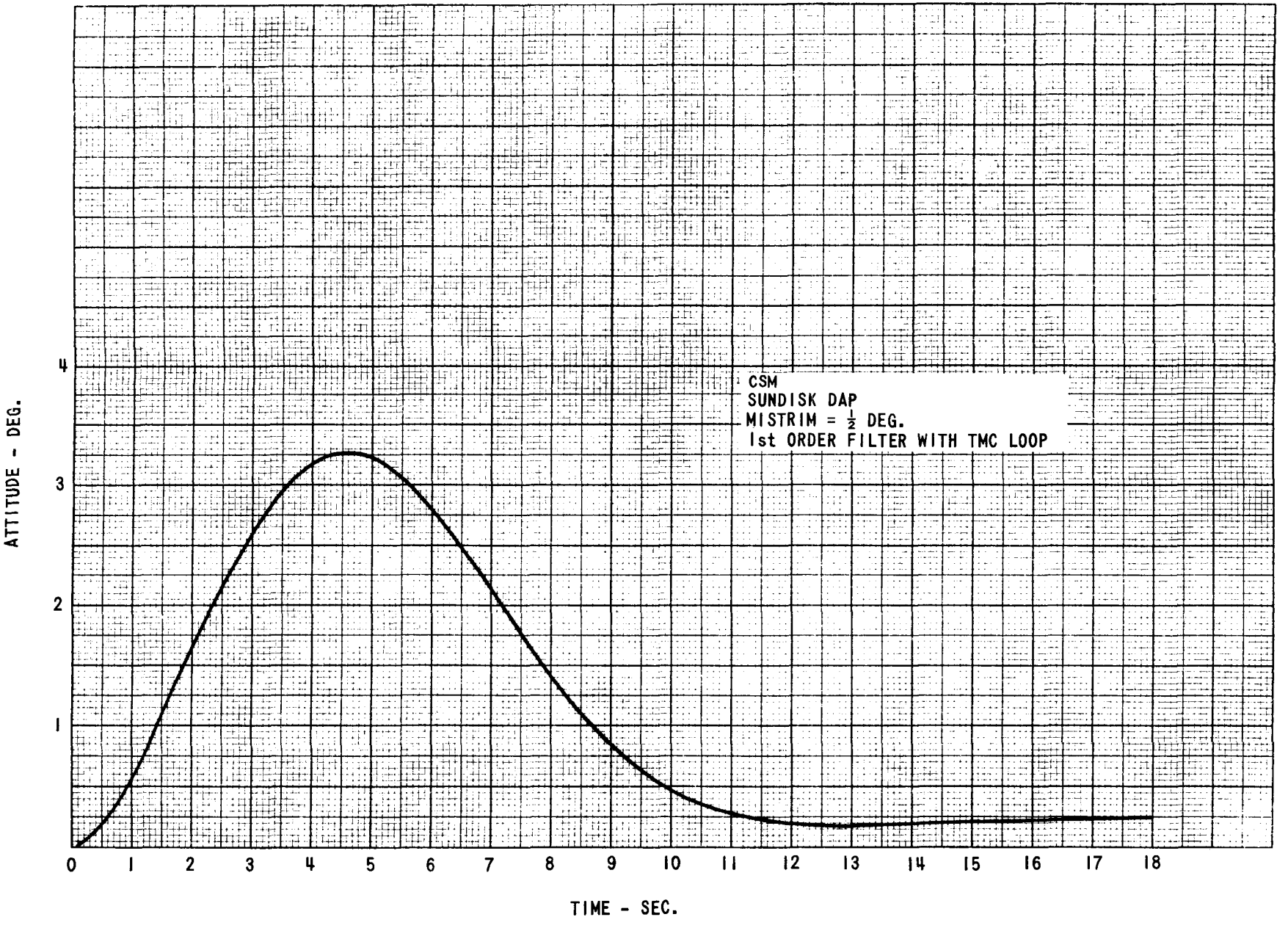
CSM
SUNDISK DAP
MISTRIM = ½ DEG.
1st ORDER FILTER WITH TMC LOOP
ATTITUDE - DEG.
1
2
3
4
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
TIME - SEC.

FIGURE 3

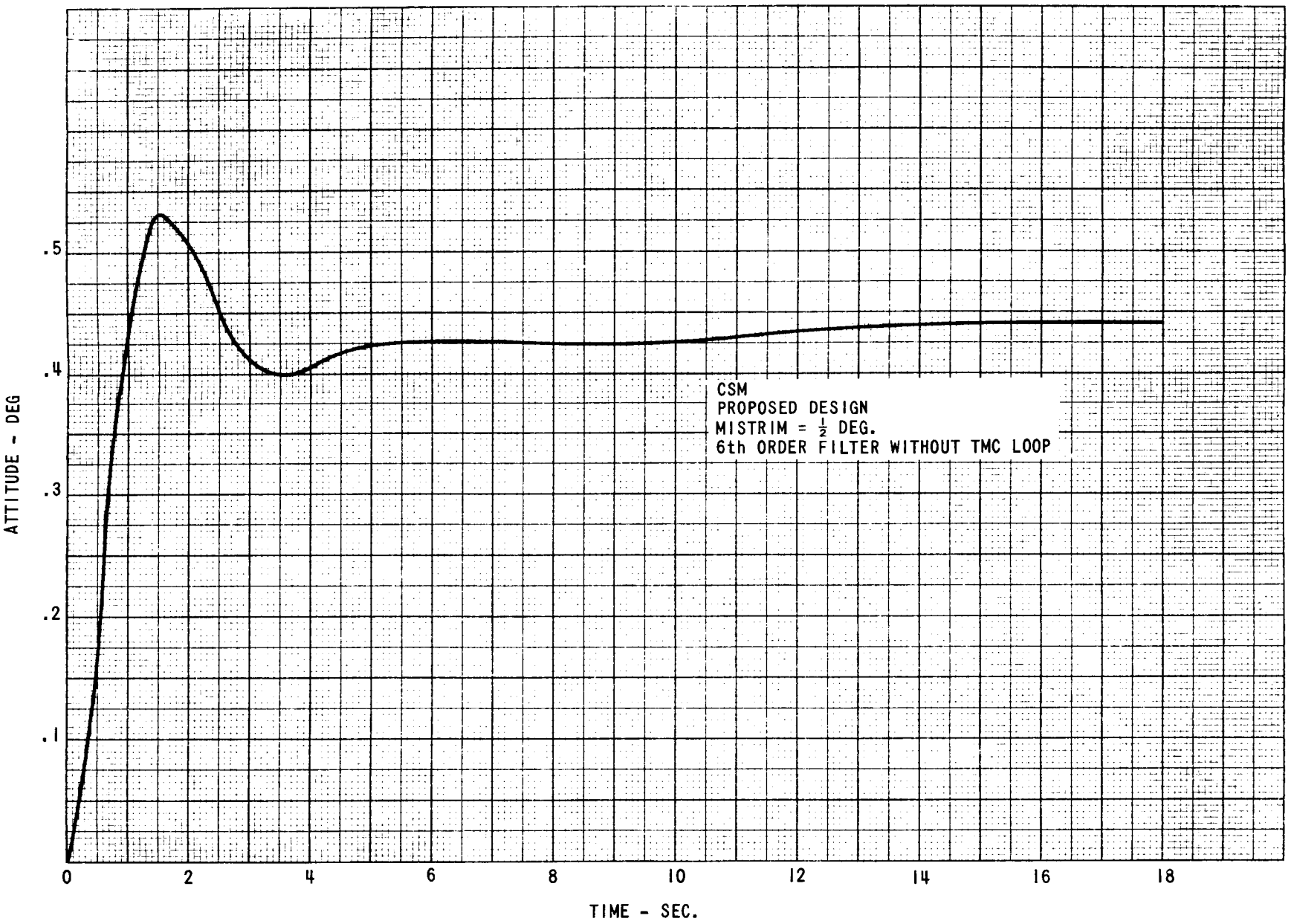
ATTITUDE - DEG
.5
.4
.3
.2
.1
0
2
4
6
8
10
12
14
16
18
TIME - SEC.
CSM
PROPOSED DESIGN
MISTRIM = ½ DEG.
6th ORDER FILTER WITHOUT TMC LOOP

FIGURE 4

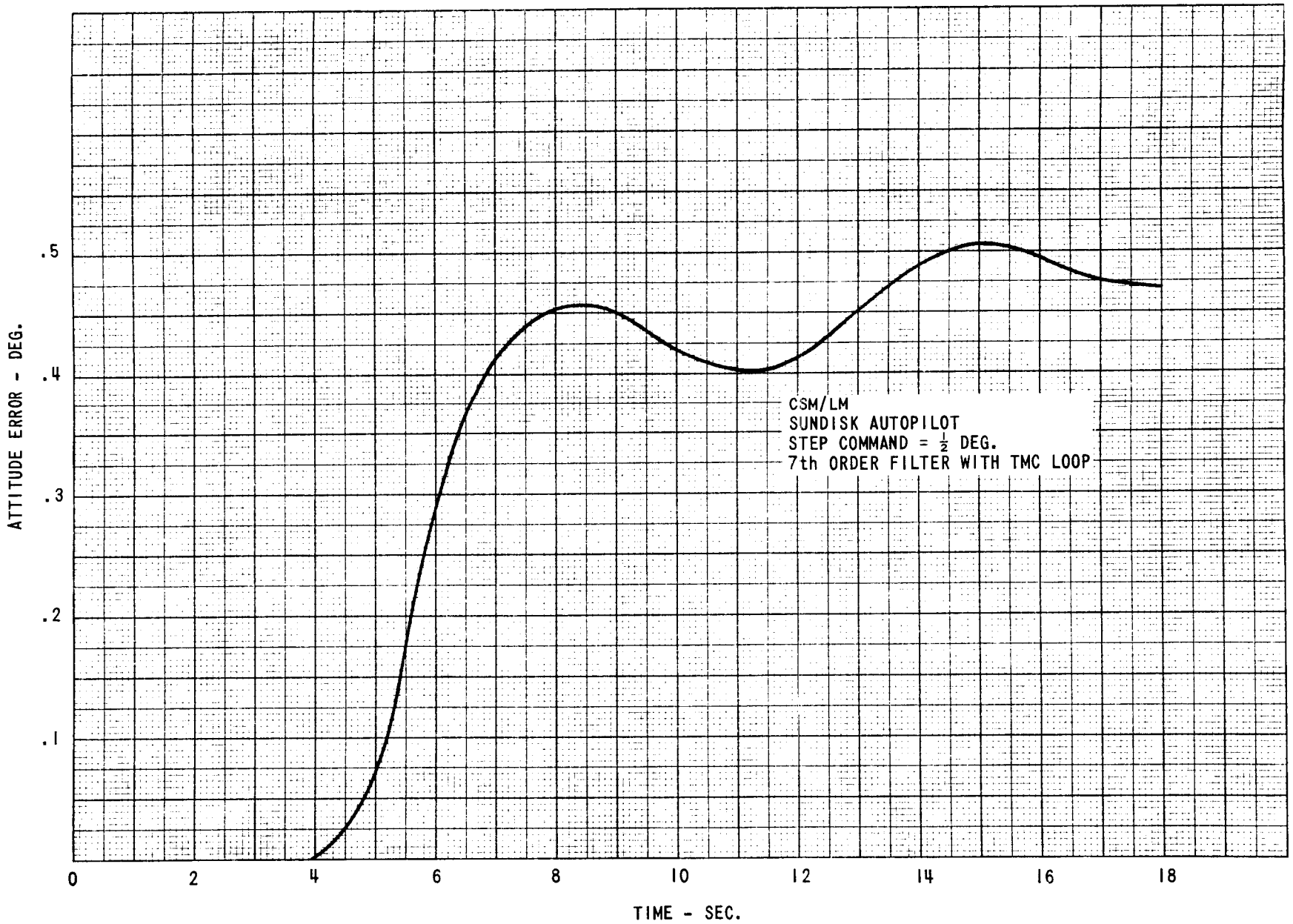
ATTITUDE ERROR - DEG.
.5
.4
.3
.2
.1
0
2
4
6
8
10
12
14
16
18
TIME - SEC.
CSM/LM
SUNDISK AUTOPILOT
STEP COMMAND = ½ DEG.
7th ORDER FILTER WITH TMC LOOP

FIGURE 5

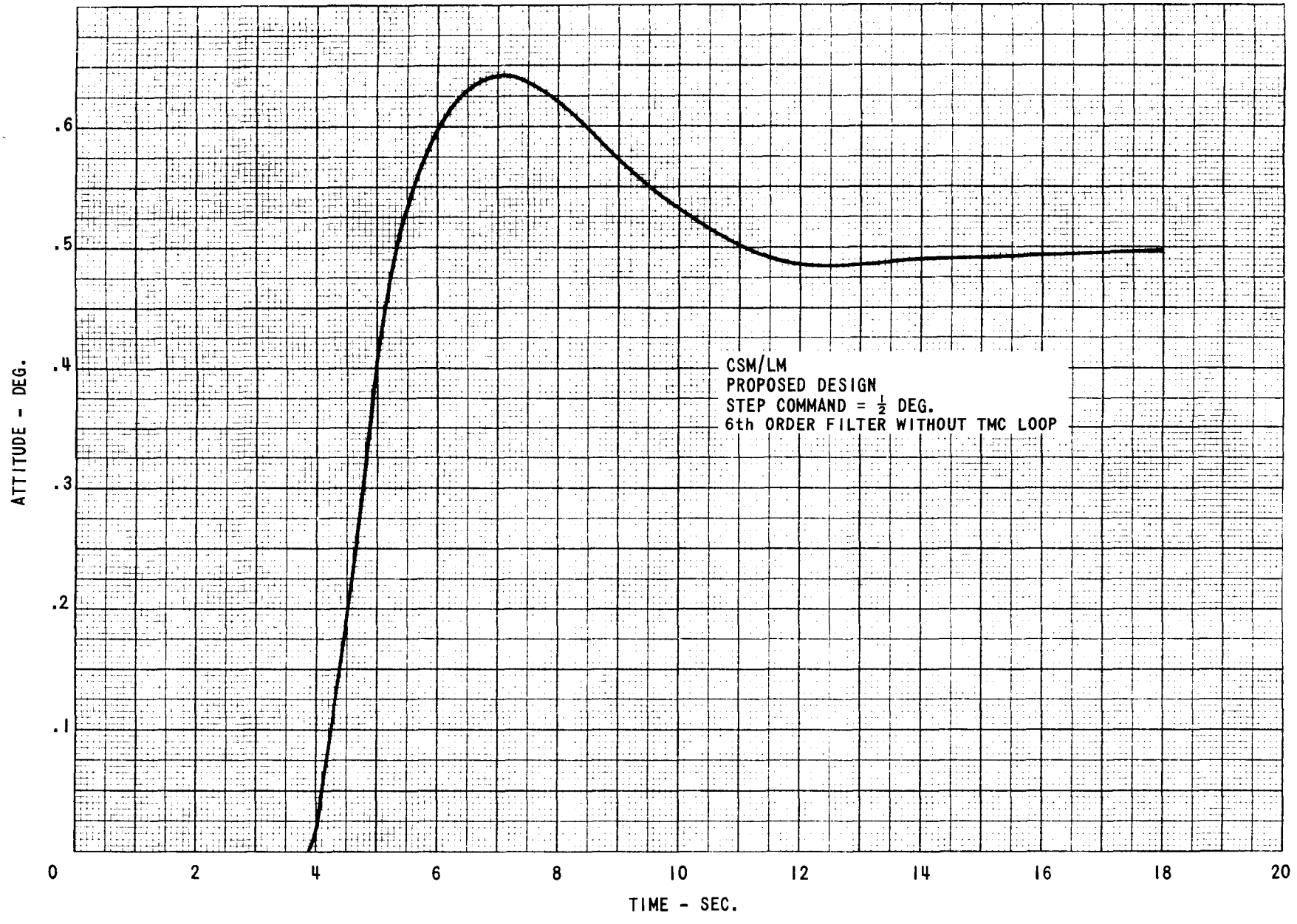
ATTITUDE - DEG.
.6
.5
.4
.3
.2
.1
0
2
4
6
8
10
12
14
16
18
20
TIME - SEC.
CSM/LM
PROPOSED DESIGN
STEP COMMAND = ½ DEG.
6th ORDER FILTER WITHOUT TMC LOOP

FIGURE 6

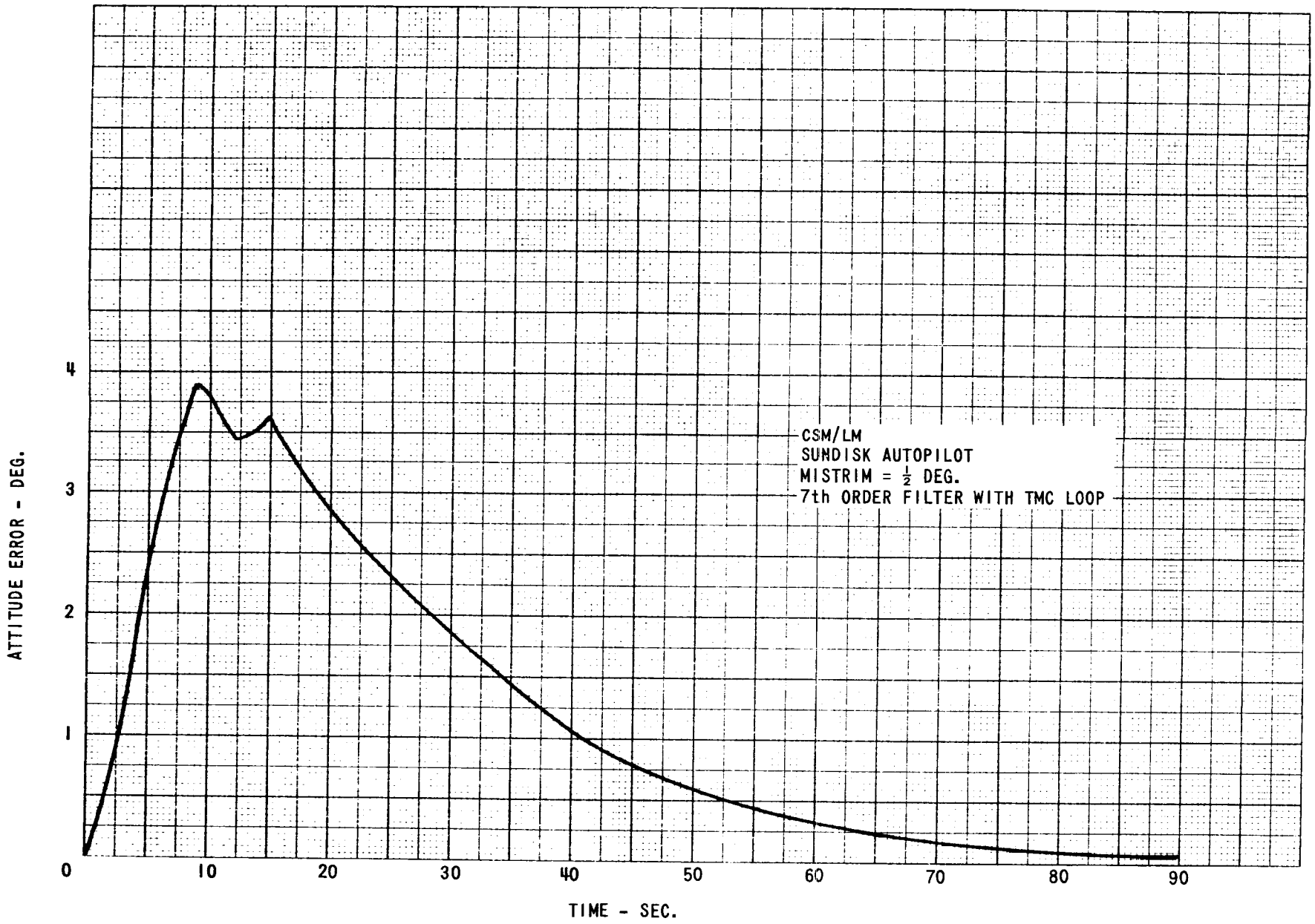
CSM/LM
SUNDISK AUTOPILOT
MISTRIM = ½ DEG.
7th ORDER FILTER WITH TMC LOOP
ATTITUDE ERROR - DEG.
0
1
2
3
4
10
20
30
40
50
60
70
80
90
TIME - SEC.

FIGURE 7

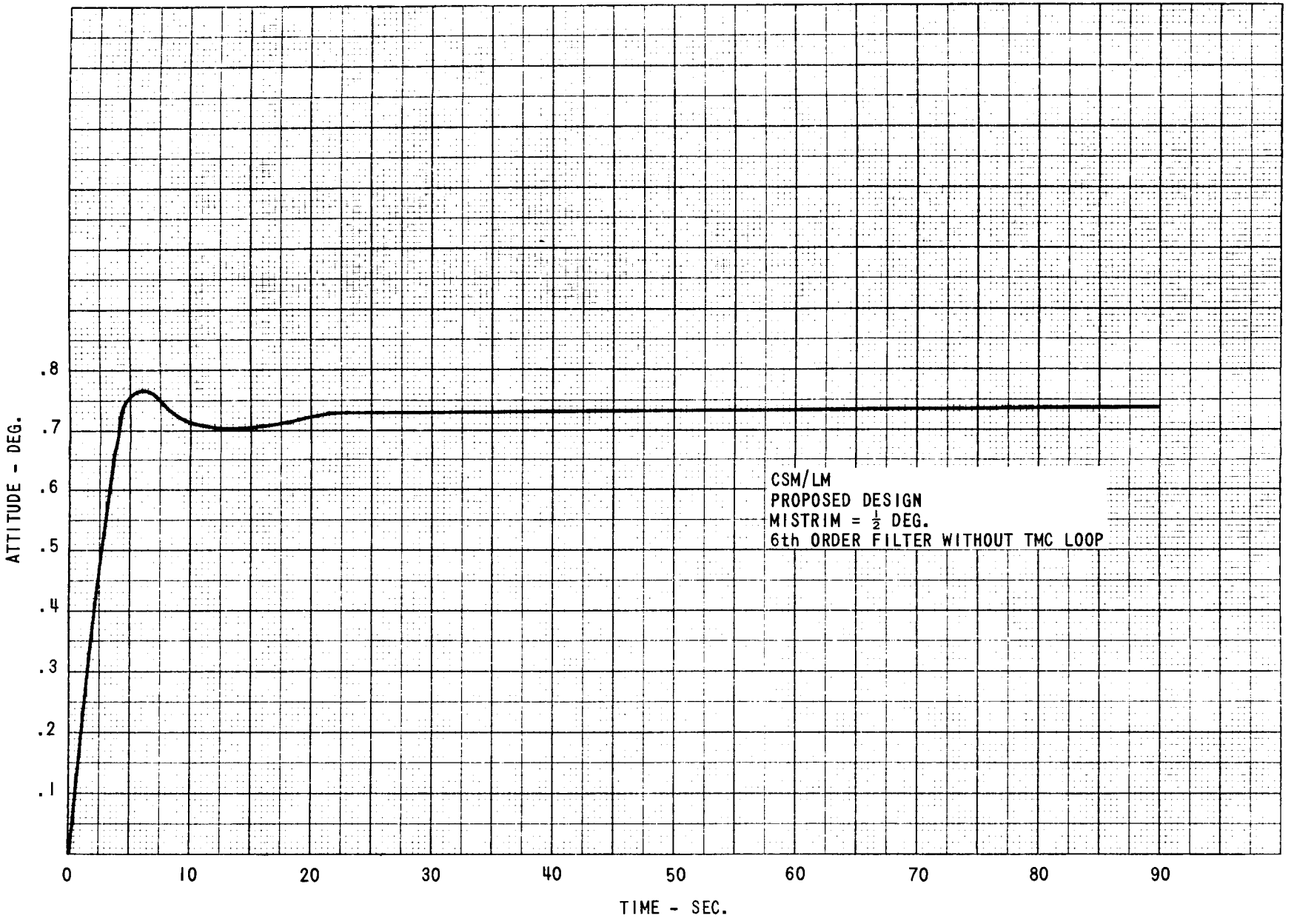
ATTITUDE - DEG.
.8
.7
.6
.5
.4
.3
.2
.1
0
10
20
30
40
50
60
70
80
90
TIME - SEC.
CSM/LM
PROPOSED DESIGN
MISTRIM = ½ DEG.
6th ORDER FILTER WITHOUT TMC LOOP

FIGURE 8

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F. La Piana

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